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http://www.holo.com/holo/gram.html

3. A Guide To Pratical Holography
-Practical Holography- Some of the questions about holography which come to mind immediately might serve as a good starting point for our discussion. They are: "What is a hologram? And how does holography work?" Note that the process... How... One...
http://www.holo.com/holo/book/book1.html

4. [redacted]
Information about the Hologram and Holography Holography is the science of recording three dimensional shapes as photographs of interference patterns of laser light waves.
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5. LASER POINTER HOLOGRAPHY
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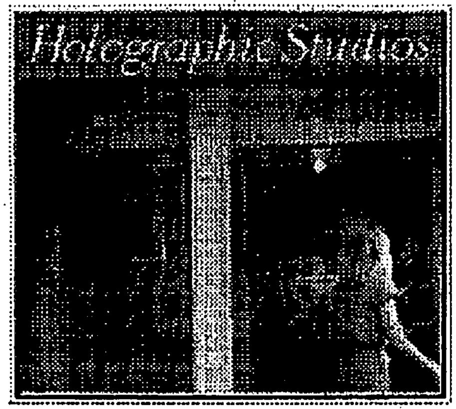

Presents:

Holography Helpers

Making Single Beam Reflection Holograms

By Jason Sapan / Holographic Studios

Search for a Holography book. Enter the keyword **Holography**.

The simplest hologram is a **single beam reflection hologram**. It can be seen in white light. It can be made with a small 5 milliwatt (mw) **Helium-Neon** (*He-Ne* pronounced *he-knee*) laser (producing a continuous red beam), a 10 to 20 power (10x - 20x) microscope objective (lens) and some holographic film. You can use a less powerful laser but you will need to make your exposure time longer. And of course if you have a more powerful laser you should shorten your exposures. Lasers that are *polarized* have more useful power for making holograms. Make sure that the laser is rated **TEM 00**, this means that when you spread the beam out with a lens there will be no dark spots. For instance TEM 01 would produce a beam with a black hole in its center and is referred to as the donut mode. *TEM* stands for *Transverse Electromagnetic Mode*, and the two numbers following are the graphic cartesian coordinates of holes in the beam. Always excercise care in using a laser. Do not point it at anyone or look directly into it.

You will need a simple darkroom with a dark green safelight with a 20 watt or less bulb at least 8 feet from the film. You need at least 3 developing trays, holographic developer (consult with the people you

purchase the holographic film from), a good holographic bleach, and a tray with water and a half a capful of Kodak Photo-Flo as a final anti spotting bath. You also need a sink. A bathroom is okay if nothing else is available. Just make sure it is light tight. You should test the safelight by placing a small piece of your holographic film out where you do your developing for about 10 to 15 minutes. Develope it and see if it is exposed by the safelight. If it is then you need more green on your filter or less light. A dimmer switch on the light can help.

The 5 mw He-Ne laser will cost around $100 - $200 US from Meridith Instruments or MWK (on the web). A microscope objective is cheap. And film costs around $5 for a glass plate. Actual plastic film costs a bit less. Plastic film on a roll is cheapest but you have to buy a lot at once. Glass plates are considered best and are easiest to use. Developing and bleach formulas are available from the people who sell you the film. Try Geola Labs or Integraph on the web.

This is the way I make single beam reflection holograms. Remember, there are many other ways to make this or any type of hologram. Feel free to experiment with the geometry.

If you can, make an **isolation table** for your hologram set up. However, it is not essential for a successful exposure, but it will help you obtain brighter holograms in a noisy environment. An *isolation table* can be as simple as floating a slab of granite, marble, or 1/4 inch thick steel on an inner tube. This acts as a shock absorber. Some people make a sandbox and float that on the inner tube. The table top should be rectangular at least 3 feet by 4 feet. Longer is better than wider. You can also work on a hard top table or a concrete floor.

Aim the **laser** through the **lens**. This will spread the beam out like a flashlight. This beam of light is called the **"reference beam"**. At a distance of about a meter or so from the *lens* mount the **holographic film**. Mount the film at a 30 to 45 degree angle to the beam. This will be the **"reference angle"** you will use when you are lighting the completed hologram and are viewing it. Once you have aligned these elements you should secure them in place so they don't move. You can sandwich the film between two pieces of quarter inch thick glass using carpenter's spring clamps. Glue the bottom rear back edge of the back plate of glass to the table top with *hot glue* available from a crafts or hardware store. Get a hot glue gun with a trigger feed. Make sure that the glue is only on the back edge. Do not touch the hot glue after it comes out of the gun. It is *very hot* and can cause *serious burns*. Wait till it cools in about a minute or so and has hardened. To remove it after it cools you can wet it with a little acetone to help break its bond.

If you are shooting glass plates you will need to make a glass plate holder. A pair of "U" channel metal rods can be glued to a bottom and top support bar so that the plate can slide down into it to the table. This holder should be hot glued to the table with buttress supports from the top of both "U" channels to the table top. The plate holder can be made of hard wood that has had grooves routed out as well. You can use some modeling clay in each corner of the plate to prevent it from moving after you slide it into the channels. The plate and object are mounted sideways. I suggest that you paint all surfaces and plate holders flat black to prevent any unwanted light from degrading the quality of your hologram.

The laser light reflecting off the object is called the **"object beam"**. It then bounces back through the holographic film where it meets the **"reference beam"**. The two beams pass through each other creating an **"interference pattern"**. This *interference pattern* is what you are photographing on the holographic film.

Mount your object sideways with the top of the object nearest to the laser, directly behind the glass (the opposite side of the glass than the laser). It helps to actually have it touch the glass. The laser beam will **"reflect"** off the object. I like to use objects that are not too deep. A good beginner's image is coins. The

choice of your object is critical to your success. The object must be very solid. Metal, ceramic, seashells, plaster, or stone are good. Paper, plastic, feathers, string are very tempermental and are not for your first attempts since they are more prone to vibration problems that might tend to ruin your exposures. The object should be colored white, red, gold, or another light color. **Black**, green, or blue will disappear in a hologram so do not use objects made exclusively of them. However these colors can be used as long as they are within light colors. Remember the laser is shining red light on your object. The color red next to the color white on your object will all look like a single color. Red print on a white background will disappear. Try viewing your object through a red filter to get a good idea of how it will look in laser light. You can use *hot glue* to adhere them to another plate of glass that you press up against the back plate (the far side) of the glass being used as your film holder. You can use more than one layer of glass plate model holders for more depth. You must glue the bottom of each model holding plate to the table surface. I like to also take wooden or metal rods and glue them at an angle from the top of each plate of glass to the table top as a flying buttress. This helps eliminate vibration problems that would cause the hologram to be dim or not work at all. The sturdier you secure the model and plate holder the more likely it is that your hologram will be successful.

Before you load holographic film you must now take a piece of black cardboard and lean it up against the front of the laser as a **"shutter"** to stop the beam of laser light from reaching the film holder.

Now take a piece of film and in the dark put a corner of it between your lips. The side that sticks to your lips is the emulsion. Place that side toward the object (i.e. the coins) and place the front plate of glass over the film and clamp it to the back plate with the spring clamps. I use three clamps. One on each side and one on the top. Now walk out of the room for at least *20 minutes*. This allows the **"camera"** you have just made to **"settle"** and prevent vibration problems. Remember light waves are incredibly small. It takes very little to move them.

Come back in the room and walk next to the shutter. Wait one minute then lift the *"shutter"* for about 15 seconds. Close the shutter. You might want to do a **bracket exposure**. In this process you cover three quarters of the film with a black card. After you have exposed the first quarter of the film you slide the black card back to allow the next quarter of the film to be exposed. Wait a minute for the system to settle and expose the film for an additional 5 seconds. Then you replace the shutter and move the black card back once again to allow another quarter of the film to be exposed. After you wait another minute to allow the film to settle again, open the shutter for yet another 5 seconds. Finally, you remove the black card completely, wait another minute, and expose a final 5 seconds. (After you develope the film you will be able to see which amount of exposure time worked best. You can then adjust future exposures sucessfully.) Take the film out from between the glass plates and develope it in your darkroom. If the darkroom is far from the film you might want to transport it there in a light proof box. Follow the procedure of development that the film manufacturer gives you. Generally, you will **develope** the film until it is **black** and then **bleach** it **clear** and wash it. I suggest you wear latex gloves and wear an apron or lab jacket. Make sure the darkroom is well ventilated. It is now safe to turn on the room lights. You will not see an image until the film is dry. You can see rainbows through the film if you hold it up to a light. This is the *diffraction* from the *interference pattern* you have just photographed on the film. It is a good sign that your hologram has worked. While it is wet the emulsion is swollen and thereby visible only to those who can see infrared light. I like to hang my holograms to dry, but you can blow dry the film in front of a fan. Don't use a hot blower. It can distort the film or start a fire.

The dry hologram is best viewed with a bright spot light (halogen is best) You can also use a clear light bulb not a frosted bulb. Do not use flourescent lighting to view holograms. It will make the image look blurry. Sunlight will work but it also will bombard the hologram with **UV rays** and tend to darken the film over a long period of time causing it to **"print out"**. It will still be a good hologram, but the film will no

longer be clear. Do not get the hologram wet once it has dried. It can erase the image or spot it permanently. If you do get it wet, quickly soak it in water and carefully redry it.

You may have some trouble finding the image the first time. Remember it must be lit with light coming from the same angle that it was created with (the **"reference angle"**). Try slowly rotating the film and turning it over until you see the holographic image. It should appear behind the film as a **"virtual"** image. It should look exactly the way your model was when you shot it (**"orthoscopic"**). If the object appears to be sideways you forgot to mount it sideways when you mounted the model. In that event its time to go back to your set up and rotate the object in your holographic camera 90 deegrees and reshoot. Now if you flip the film over the holographic image will appear to jump out in front of the film as a **"real"** image. This image is inside out or **"pseudoscopic"**. It helps to have a piece of black card stock behind the film to make it easier to see.

Congratulations! You are now a holographer! Let me know how you did.

Summary:

Reflection holograms are made by **interfering** the **reference beam** with the **object beam** from **opposite sides** of the holographic film. It is visible in white light.

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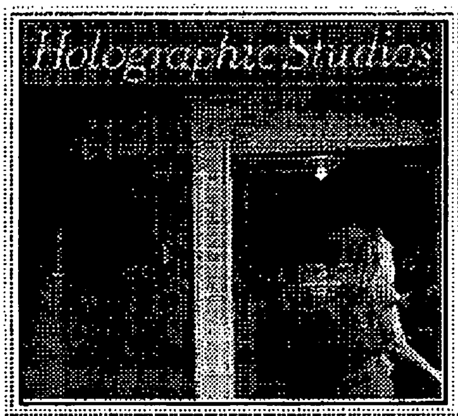

FREQUENTLY ASKED QUESTIONS

By Jason Sapan / Holographic Studios

Search for a book about **Holography** on our search engine. Type the Keyword: **Holography**

- **Can you suggest any good books on holography?**
  My favorite is "Practical Holography", by Graham Saxby, published by Prentice Hall, London. The "Holography Handbook" by Fred Unterseher, published by Ross Books, Berkeley, CA, is a good beginner's guide. These and other books on the subject can be found at Barnes & Noble.

- **Is the right word *Hologram* or *Holograph*?**
  *The preferred word is **Hologram**. The dictionary defines a Holograph as a hand written document, as in a holographic will or deed. A **Holographer** is someone who makes holograms. **Holography** is the word for the technology and artform. According to Isaac Asimov, a **Holographist** is a person who collects or studies holography but does not make holograms. Things pertaining to holography are said to be **Holographic**.*

- **What is a hologram?**
  A hologram is a photograph of light wave interference

- **Are holograms projections?**
  No, holograms are not projected. Light fills up a hologram like plaster would fill up a cast. Technically, they are reconstructions of the light that reflected off the object.

- **If a hologram breaks is the whole image visible in each piece?**
  No, each broken piece would let you see the image from its own unique perspective. Think of a hologram as a window. Anywhere you look through a window you see what's on the other side. If you were to paint the window black and scratch a hole in the paint on the left side of that window just big enough to look through, you would see everything on the other side of the window. Like looking through a peephole. If you then scratch another viewing peephole somewhere on the right side of the window, you still can see through, but from a different perspective. This is the same effect that each broken piece of a hologram would display. Just remember that if you have two broken pieces taken from opposite sides of the hologram, and you are looking at an object that looks differently from each side, one piece may let you see just one of those sides while the other piece will let you view the other side. So, you might say that each piece of a hologram stores information about the whole image, but from its own viewing angle. No two pieces will give you a view that is exactly the same.

- **How many lasers do you need to make a hologram?**
  One. However, you can shoot several different holograms on the same piece of film. Each holographic exposure can be shot with a different color laser if, for example, you are making a multi color image of red, green, and blue. A color hologram can also be made with a single laser using tricks of the trade like emulsion swelling or multiple reference angles.

- **What does the word *LASER* mean?**
  It is an acronym or abbreviation of the first letters of Light Amplification through Stimulated Emmission of Radiation.

- **What is colo r?**
  Light is a wave. We see differnt sizes of light waves as different colors. Its something like the sizes of the strings of a harp making different musical notes. The largest strings of a harp make the lowest pitch notes and the shortest strings make the highest pitched musical notes. A rainbow is like a harp with strings of light. The largest visible light waves are called red. Those a little smaller are called orange. A bit smaller and we get yellow. Smaller still is green. Smaller once again and we have blue. And the tinyest visible light waves are violet. Light waves smaller than violet are invisible and called ultraviolet. Light waves larger than red are also invisible and called infrared. The visible spectrum is from 400 nm (nanometers - one billionths of a meter) for violet to 700 nm for red.

- **Is there a word to describe where an image appears in a hologram?**
  *Yes, there are a few common ones that are quite helpful. If an image appears to be on the other side of the hologram, like looking through a window, it is called **virtual**. If an image jumps right out of the hologram and appears in front of the film, it is called **real**, since it has left the "virtual" world inside the film and entered the "real" world. When you flip a hologram over, the image is*

inside out and called ***pseudoscopic*** *. Flip it back over and view it normally, right side out, and it is called* ***orthoscopic***. *An image can be orthoscopic and real or orthscopic and virtual. Or an image can be pseudoscopic and real or pseudoscopic and virtual. An image can be both real and virtual, as in the case of an image that starts behind the film and then protrudes right out of it. Holograms can be made (especially by artists) that have both orthoscopic and pseudoscopic images in them. Any combination of these terms is possible. So, to quickly rehash,* ***Real*** *= in front;* ***Virtual*** *= behind;* ***Orthoscopic*** *= right side out;* ***Pseudoscopic*** *= inside out.*

- **How are images made to jump out in front of the holographic film?**
  As just explained in the previous response, images that protrude out in front of a piece of holographic film are called ***real*** *images.* ***Virtual*** *image holograms are used as the masters for* ***real*** *image holograms. Most* ***real*** *image holograms are holograms of holograms. The basic concept is like the idea that a negative of a negative is a positive. In effect, when you typically make a hologram it is* ***orthoscopic*** *(right side out) and* ***virtual*** *(the image appears behind the film). If you turn this* ***orthoscopic*** *and* ***virtual*** *image hologram over the image you see is both* ***pseudoscopic*** *(inside out) and* ***real*** *(in front) since the spatial relationship of where the image is seen has flipped. If you usethis image to record a second hologram, that image will be* ***pseudoscopic*** *(inside out) because you are recoding the* ***pseudoscopic*** *image of the first hologram and* ***virtual***. *If you then turn it over it is* ***orthoscopic*** *(right side out) because an inside out image of an inside out image is right side out and* ***real*** *because each time you flip a hologram over you reverse from virtual image to real image. Voila!*

- **How are Single Beam Holograms made?**
  Read my page on Making Single Beam Reflection Holograms.

- **Is vibration important in holography?**
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This page is a work in progress. Latest update November 9, 1998.

Interference Can Stop Things

By Jason Sapan

Holographic Studios

Holograms are photographs of three dimensional impressions on the surface of light waves. Therefore, in order to make a hologram you need to photograph light waves. This presents something of a dilema.

As we all know, it can be problematic to take a photograph of a quickly moving object. If you've ever had a picture come back blurred from the film lab, you know all too well. When a person moves too quickly in a photograph, their image blurs. And they are only moving at about 20 miles an hour. Try to imagine the problems associated with trying to photograph a photon. To start, a light wave moves at the speed of light. Thats about 186,000 miles per second. Thats more than half way to the moon in a second. Considerably faster than someone's hand waving. In fact, its so fast that the very idea of even capturing it on film would appear impossible. What we need is a way to stop the photon so it can be photographed. And this technique is called INTERFERENCE.

Imagine yourself standing on a small bridge over a pond of still water. Lets further imagine that you were to drop a pebble into the pond. As it hits the water it creates a circular wave. This wave radiates outwards in an ever growing circular path. We've all done this.

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Now, if you drop two pebbles in the water, you would create two circular waves, each of which would grow in size and eventually cross the path of the other wave and then continue on its individual expanding path. Where the two circular waves cross each other, you might say that they interfere with each other. And the pattern that they make is called an interference pattern. Not too difficult to envision. This is what interference is. Two waves interfering with each other as they cross paths. No permanent impact is left on either wave once it leaves the area of overlap. Each wave looks exactly the same as it did before it crossed the other waves path. Well, maybe its grown a little bit bigger, but that's about it. So, what's the big deal about interference in that case?

Here it is. As waves cross paths and interfere, the pattern they make is called a standing wave. It is called a standing wave because it stands still. And since it stands still, it can be photographed.

This solves the problem of how we can photograph something moving at the speed of light. But it doesn't answer the bigger question. Why does it stand still?

To understand that, lets envision a photon. Remember? It looks like a corkscrew. And if we view it from the side it looks like a sine wave. Now, try to imagine a river whose streambed lies on a wavy rock formation that looks like a sine wave. This river would be full of

rapids. In fact, it would be great for white water rafting. Although the water in the river is flowing furiously downstream, the pattern of water above the rapids is stationary. You might think of it as a standing wave. The wave energy is flowing through this standing wave without altering it and vice versa. It is just a momentary pattern that the water takes as it passes over a bump.

When two light waves pass through each other each wave acts like a bump to the other. Their respective corkscrew shapes interact. And the result is like rapids of light. The standing wave patterns are stationary even though the light waves energy continues to move.

When waves meet they perform addition and subtraction. When two waves of equal size meet at their high points (called crests), they add together to make a wave twice as high at that point. Conversely, where two waves of equal size meet at their low points (call troughs) they add together to become twice as low. And when one wave at its high point meets another wave at its low point they subtract and cancel out. But it isn't really cancelled out in the sense of being destroyed. Its more a case of there being no light at that spot. If you follow the wave down its path just a drop further it will be meeting the other wave at a different relationship and once again be visible. Its a situation of infinite possibilities. Just like the patterns possible as the waves of two pebbles meet in a pond. At any point you may notice that the standing wave pattern has produced a place where the waves have added together to get higher or subtracted to become lower or even just gone

flat. There's a few terms that are used to describe the possible encounters. If the waves add and get higher its called CONSRTRUCTIVE interference. If the waves subtract or cancel altogether its called DESTRUCTIVE interference.

I like to think of the interference pattern as a fingerprint of the encounter of two individual waves. Each object you make a hologram of creates its own interference pattern that identifies it.

In holography, there are two basic waves that come together to create the interference pattern. First and foremost is the wave that bounces off the object we are making a hologram of. Since it bounces off the object, thereby taking its shape, it is called the OBJECT wave. You can't have interference without something to interfere with. So a second wave of light that has not bounced off an object is used to perform this function. It is called the REFERENCE wave.

When an object wave meets a reference wave creating a standing wave pattern of interference, it is photographed and called a hologram.

Questions?

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